



# *Beam Physics at the Frontier of: Space, Time, Matter and Energy Scales*

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Presented by  
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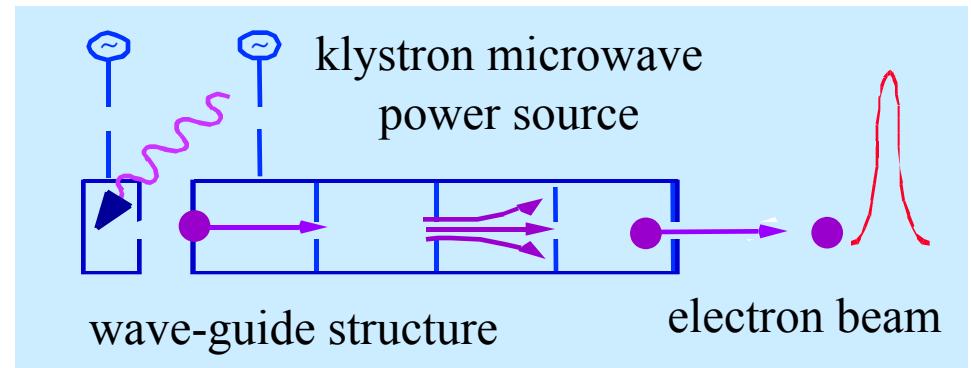
# Beams under Extreme Conditions

## HIGH FIELD

### Today's technology :

Conventional rf linacs, kms in length

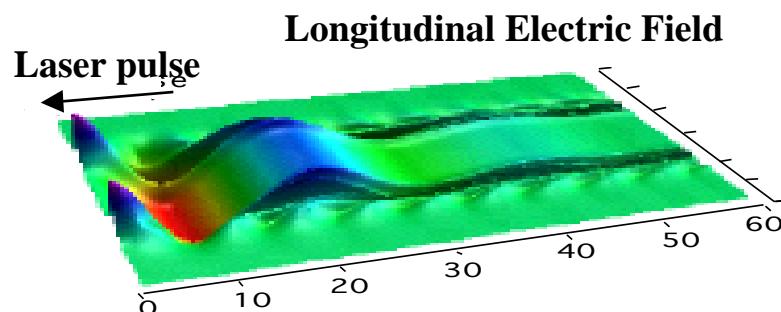
$E_z$ : 10 - 200 MV/m



### Future potential :

Laser-driven, plasma-based linac,  
cms in length

$E_z$ : 10-100 GV/m





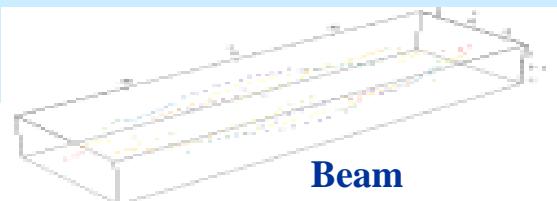
# Beams under Extreme Conditions

## LOW TEMPERATURE

Title:  
Frozen particle beam  
Creator:  
jgkern@lbl.gov 3-2610  
Preview:  
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with a preview included in it.  
Comments:  
This EPS picture will print to a  
Postscript printer, but not to  
other types of printers.

Potential  
 $V(x,y)$

Frozen particle beam in a two-dimensional quartic potential under cooling.



*Today:*

$$10^4 \text{ eV} \leftrightarrow 1000 \text{ \AA} \quad \tau_{\text{cool}} \sim 1 \text{ sec.}$$

*Future Potential:*

$$kT_{\perp} \leftrightarrow e^2 / r$$

$$1 \text{ eV} \leftrightarrow 1 \text{ mm} \quad \tau_{\text{cool}} \sim 10^{-4} \text{ sec.}$$

Macroscopic Coulomb Crystal

### *DISCOVERY*

Diffraction - and Quantum Limited Particle & Photon Beams; Crystalline Beams, Quantum Computing; Condensate Beams; Exotic Atoms

### *TECHNOLOGY*

Optical Laser and Laser-undulator Cooling



# Beams under Extreme Conditions

## LOW TEMPERATURE

### TRANSIENT BEAMS

*Today:*

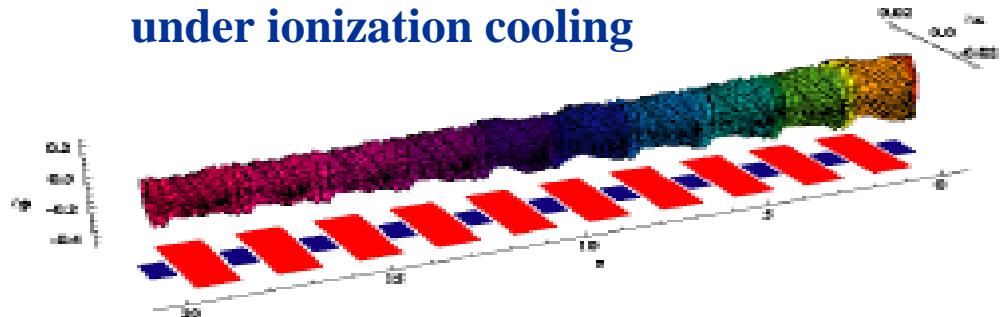
None in the laboratory

Cosmic ray bursts of hot muons

*Future Potential:*

20 GeV -1 TeV Cold Muons

Muon beam phase-space profile under ionization cooling



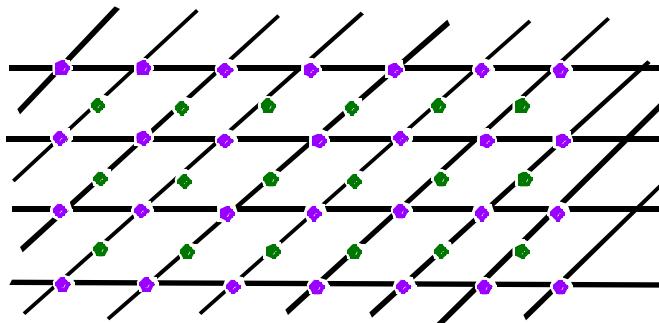
Initial transverse temperature: 11.9 eV

Final transverse temperature: 7.2eV

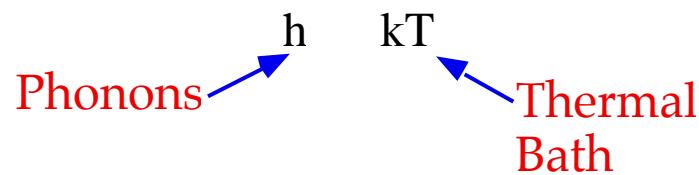
TECHNOLOGY  
Ionization Cooling  
Optical Stochastic Cooling



# DYNAMICS ON A SURFACE



Lattice vibrations and 'Phonon' spectrum characterized by Debye time-scale :



Lattice relaxation time :

$$= -1 = h / kT \sim 100 \text{ fs} @ \text{ room temp.}$$

e.g. PHASE TRANSITIONS like surface melting etc. take place on these 1 - 100 fs time-scale.  
EXTREMELY VALUABLE INFORMATION for SEMICONDUCTOR PHYSICS. e.g. Silicon



# Frontier of Beam-Plasma Science



## Beams Under Extreme Conditions

### High Field

$E \sim 100$  GV/m via  
Laser Acceleration

Today's technology:  
 $E < 100$  MV/m e.g. 50 GeV  
in 3 km @SLAC

INVENTION  
Compact Accelerators

### Low Temperature

$kT_{\perp} \leftrightarrow \frac{e^2}{r}$   
 $1 \text{ eV} \leftrightarrow 1 \text{ mm}$   $\tau_{\text{cool}} \sim 10^{-4}$  sec  
Macroscopic Coulomb Crystal

Today:  
 $10^4 \text{ eV} \leftrightarrow 1000 \text{ \AA}$   
 $\tau_{\text{cool}} \sim 1 \text{ sec.}$

DISCOVERY  
Crystalline Beams; Cold  
MUONS; Condensate Beams

### High Density

$\rho \sim 10^{18} - 10^{24}/\text{cc}$   
 $\lambda_d = \text{interparticle distance}$

Today:  
 $\rho \sim 10^{13} - 10^{14}/\text{cc}$

TECHNOLOGY  
High energy-density laser-  
plasma-beam interaction

### Ultrashort Bursts

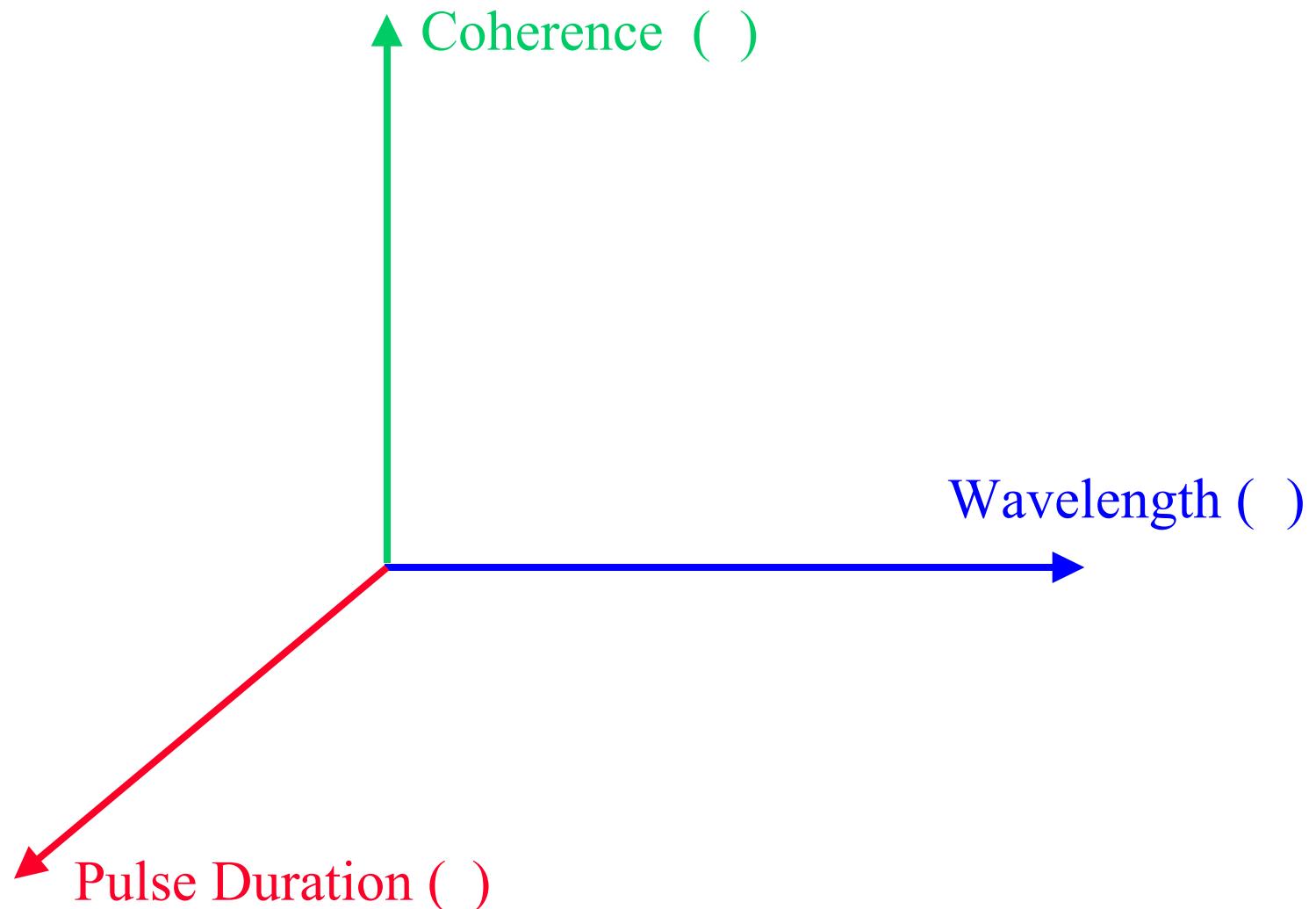
$\tau \sim 10^{-18} - 10^{-15}$  second  
Ultrashort electron and  
x-ray bursts

Today:  
 $\tau \sim 10^{-14}$  seconds

TECHNOLOGY  
Optical manipulation  
of beams & plasmas

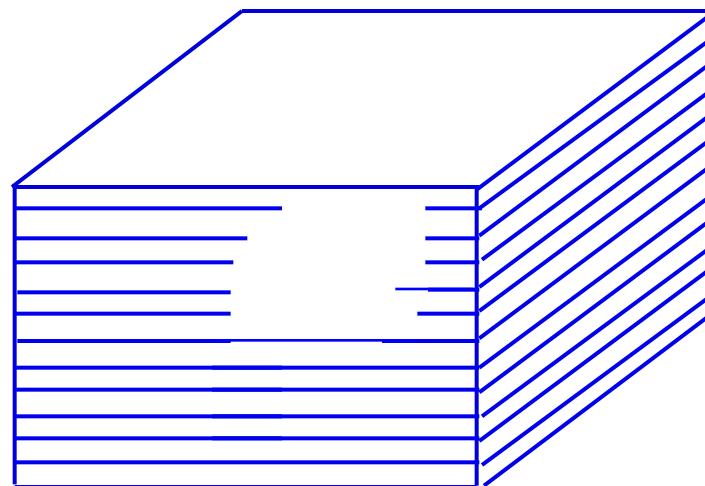


# Electron & Radiation Source Characteristics



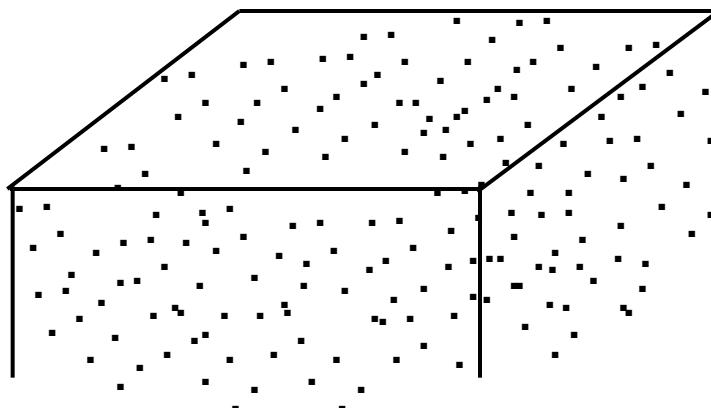


# Electron & Radiation Source Characteristics



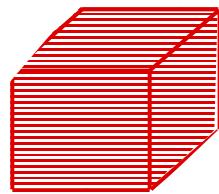


# Electron & Radiation Source Characteristics





# Electron & Radiation Source Characteristics





# Electron & Radiation Source Characteristics

“Attosecond”  
Sources of  
Electron & X-ray





# Ultrafast Coherent Chemical Reactions

